

Tampering & Aftermarket Defeat Devices

Summit with New Jersey DEP and EPA Region 2
Edison, NJ
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Agenda

- Clean Air Act (CAA) prohibited acts and emissions standards
- Vehicle and engine emission control devices (ECDs)
 - Combustion 101
 - Overview of common emission control devices
- What is an aftermarket defeat device? What is tampering?
 - How do aftermarket defeat devices work?
 - How are they installed?
- Broad overview of the industry
- What is the emissions impact of tampering?
 - Emissions testing
 - Emissions increases due to tampering

Scope is primarily aftermarket industry and not the vehicle and engine manufacturers

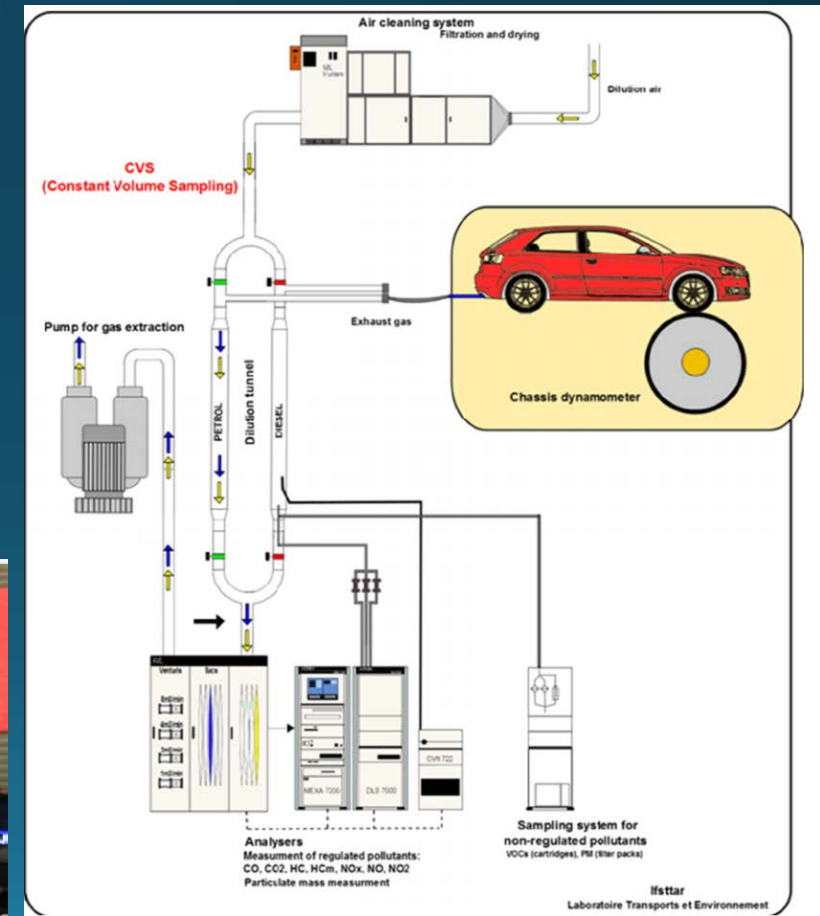
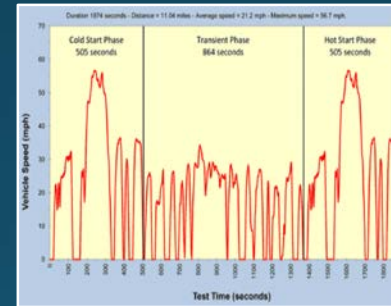
Exhaust Emission Standards

- Two Types of Exhaust Standards
 - Chassis based standards (g/mile)
 - Standards: 40 CFR Part 86 Subpart S
 - Procedures: 40 CFR Part 86 Subpart B and 40 CFR Part 1066
 - Engine based standards (g/bhp-hr)
 - Standards: 40 CFR Part 86 Subpart A and N, and 40 CFR Part 1036
 - Procedures: 40 CFR Part 1065 and 1036

Engine Dynamometer Testing

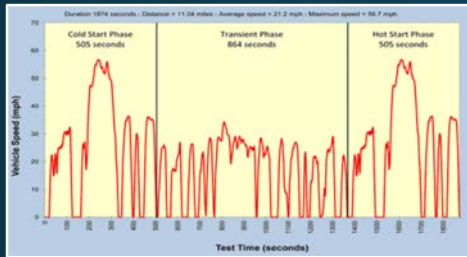


Chassis Dynamometer Testing

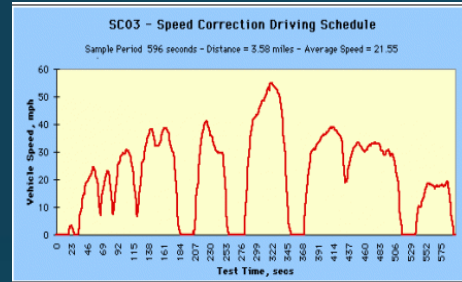


EPA Dynamometer Test Cycles

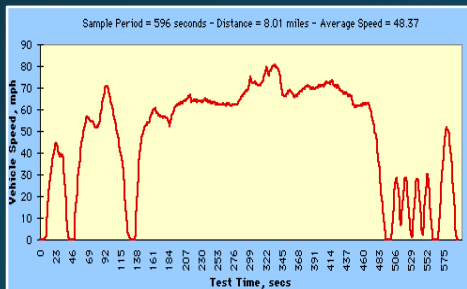
Chassis Dyno Testing:
vehicle speed vs. time



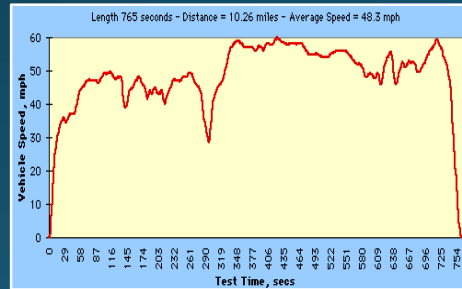
FTP-75 - City Driving (cold start)
40 CFR Part 86 Appendix I (a)



SCO3 (A/C On, High ambient temp)
40 CFR Part 86 Appendix I (h)

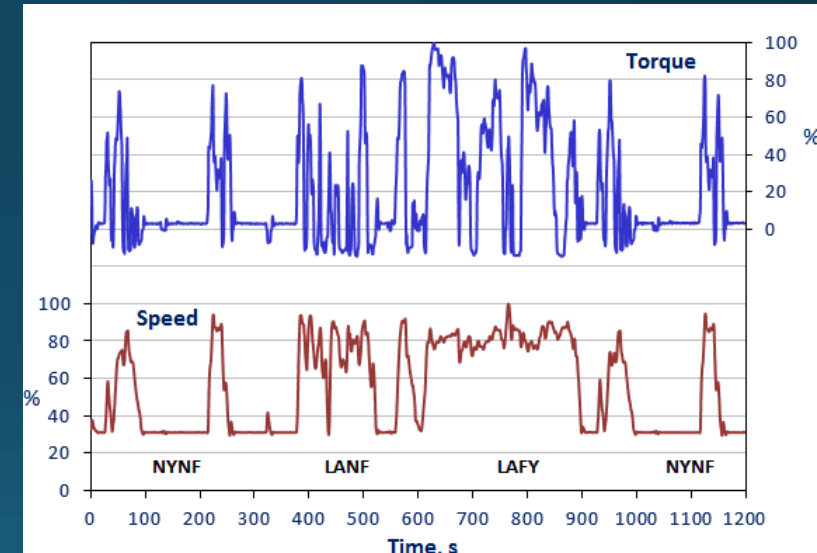


USO6 - Aggressive Driving
40 CFR Part 86 Appendix I (g)



HWFE - Highway Driving
40 CFR Part 600 Appendix I

Engine Dyno Testing:
engine load/speed vs. time



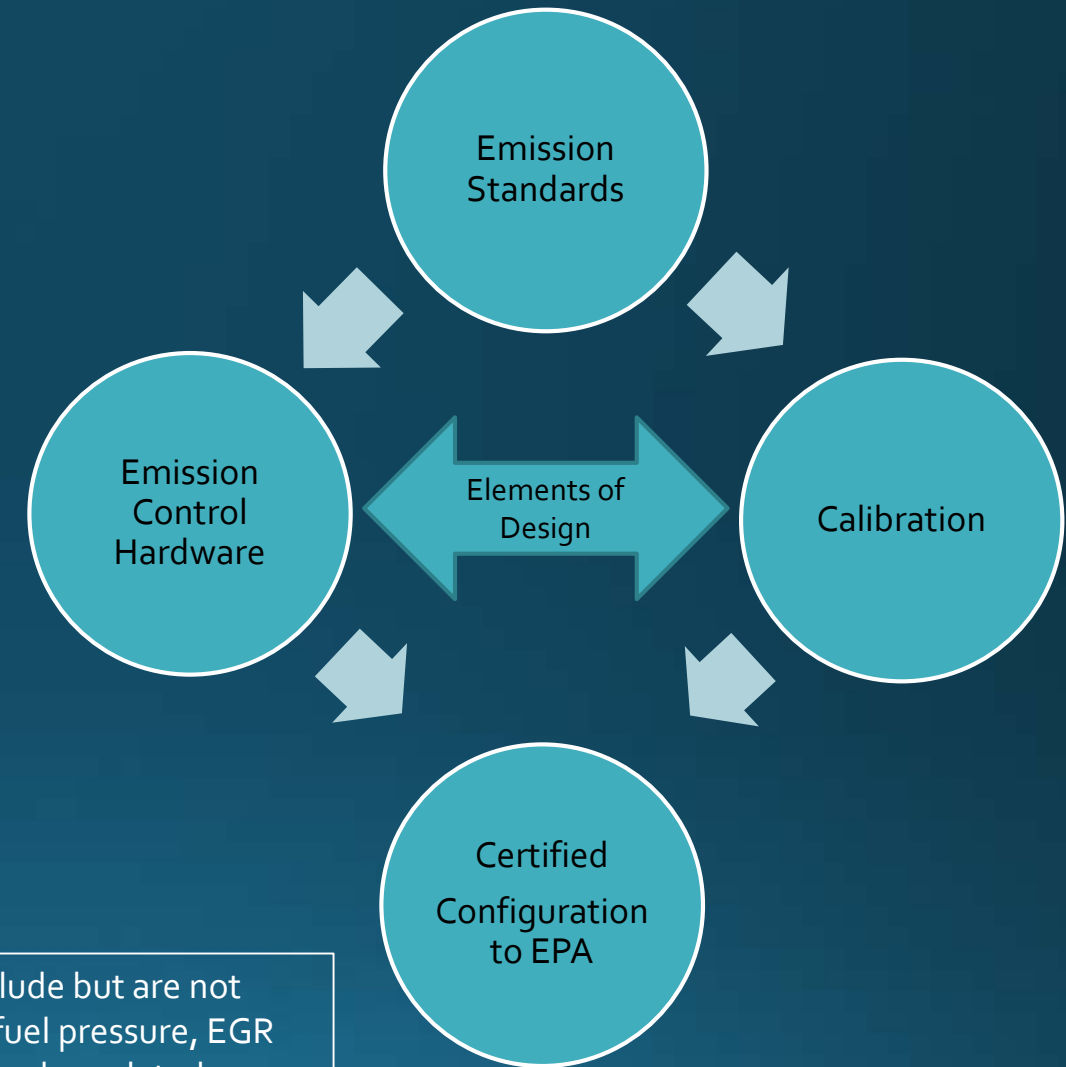
FTP Transient

EPA Certification

- Emissions Standards - Regulations do not require use of specific emission control devices
- OEM must certify a “configuration” with EPA that meets standards. Includes all elements of design:
 - Emission control device hardware
 - Calibration (engine maps)
 - Other parts of certification: Adjustable parameters, auxiliary emission control devices

Element of design is “..any control system (i.e., computer software, electronic control system, emission control system, computer logic), and/or control system calibrations, and/or the results of systems interaction, and/or hardware items on a motor vehicle or motor vehicle engine.” 40 C.F.R. §§ 86.094-2 and 86.1803-01.

Application for certification must include basic calibration information. Examples include but are not limited to: “...fuel pump and fuel pump flow rate, fuel pressure regulator and regulated fuel pressure, EGR valve and EGR exhaust gas flow rate at specified vacuum levels, EGR vacuum regulator and regulated vacuum, EGR orifice and orifice diameter, basic engine timing, timing RPM, idle rpm, spark plug gap, oxygen sensor output (mV), and thermostat opening temperature.” §§ 86.044-01(e)



CAA §203 (a)(3) and Memo 1A

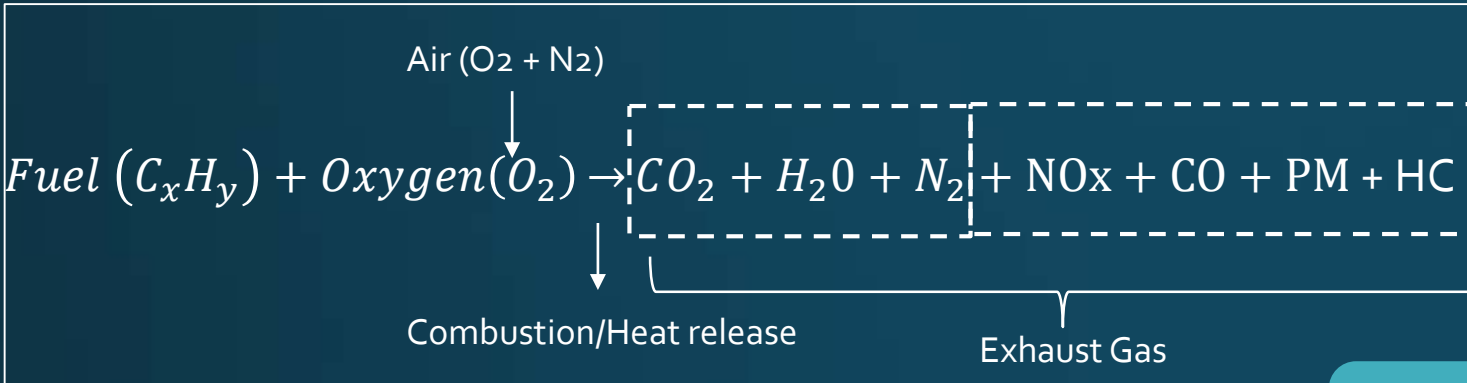
- CAA §203 (a)(3) – **Prohibited Acts:**

- Tampering: "...remove or render inoperative any device or element installed on or in a motor vehicle or motor vehicle engine in compliance with regulations..."
- Defeat Device: "...manufacture or sell, or offer to sell, or install, any part or component...where a principal effect...is to bypass, defeat, or render inoperative any device or element of design installed on or in a motor vehicle ..."

- Memo 1a, **EPA's Tampering Enforcement Policy for Vehicles and Engines:**

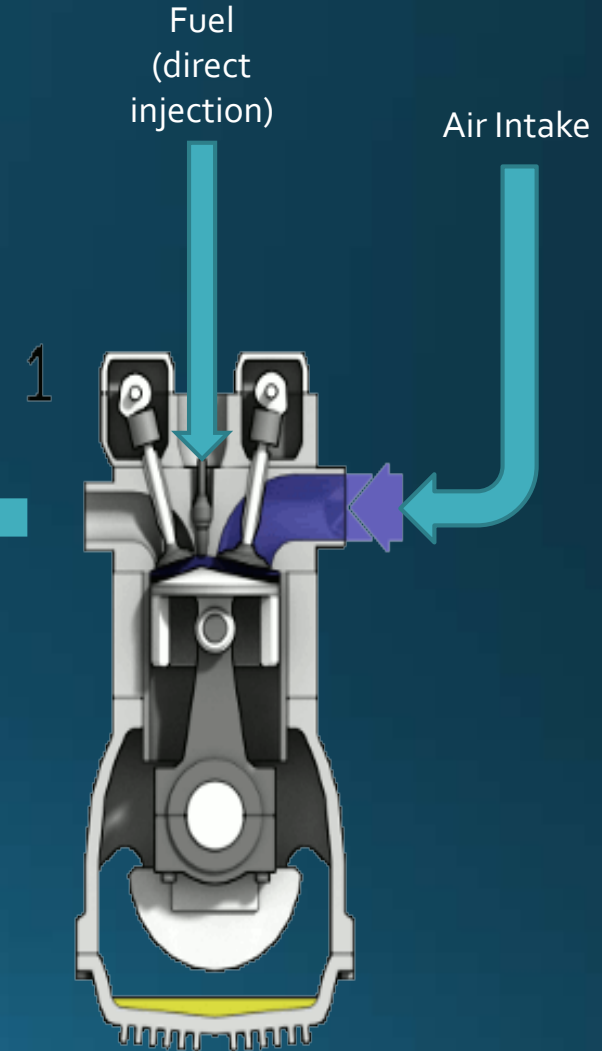
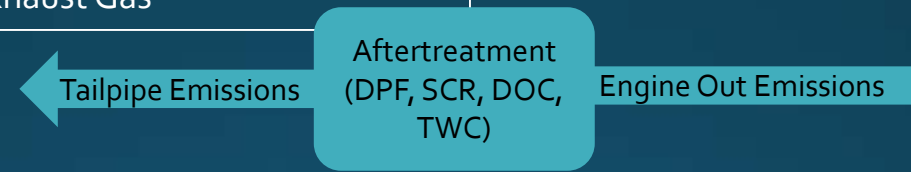
- EPA will generally take no enforcement where the person can show a "...reasonable basis for knowing that such use will not adversely affect emissions performance..."
- Examples
 - Oil filter replacement – Will not impact emissions based on engineering judgement
 - Aftermarket performance part – May affect emissions so must be tested. Some tuners, air intakes, and CAT-back exhaust systems have approved CARB Executive Orders (EOs).

Internal Combustion 101



Two Basic Types of Emission Control

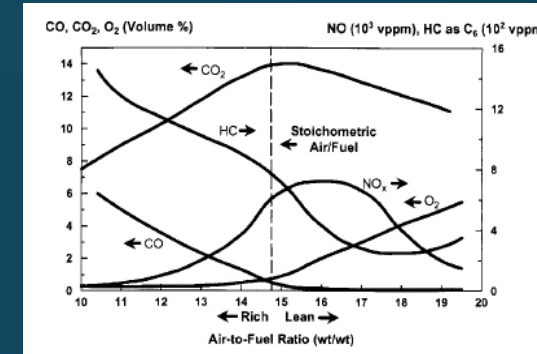
- Engine out emission control accomplished by modifying or controlling combustion characteristics, mainly cylinder temperature and pressure.
 - Air/fuel mixture ratio
 - Fuel injection or spark timing
 - Fuel injection pressure
- Aftertreatment emission control
 - DPF, SCR, DOC, TWC



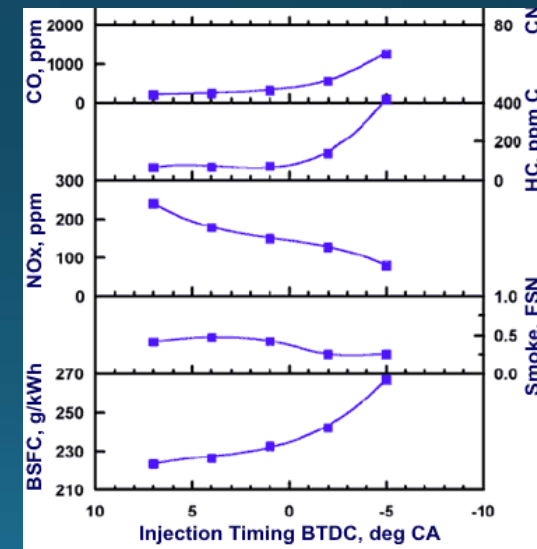
https://upload.wikimedia.org/wikipedia/commons/d/dc/4StrokeEngine_Ortho_3D_Small.gif

Combustion and Engine Out Emissions

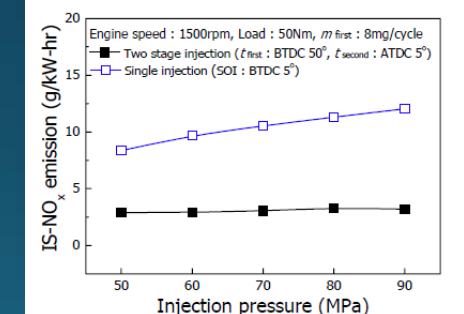
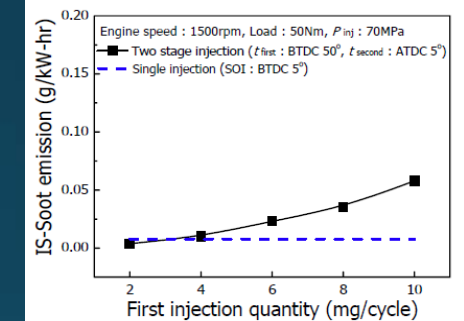
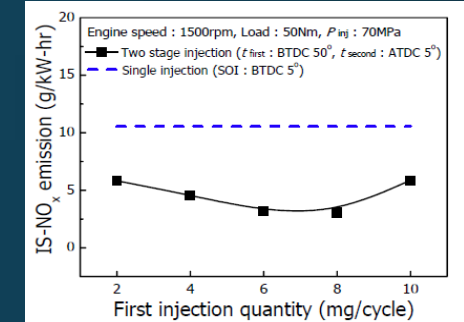
Parameter	Parameter Description	Qualitative Impact on Emissions
A/F Ratio	Mass ratio of air to fuel present during the combustion process (unitless). Stoichiometric ratio for gasoline = 14.7 Stoichiometric ratio for diesel = 14.6	Lower AFR (fuel rich) can increase power but may increase engine out CO, HC, and PM. Higher AFR (fuel lean) can increase fuel efficiency but may increase engine out NOx.
Fuel injecting timing (direct injection)	Angle of the crankshaft position in which fuel is injected into the cylinder. Typically measured in degrees, either before or after top dead center (TDC).	Advancing timing can increase fuel efficiency but may increase engine out NOx.
Fuel quantity	Amount of fuel injected into the cylinder per stroke, typically measured in units of milligrams (mg).	Adding more fuel can increase power but can may increase CO, HC, and PM.
Fuel injection pressure	Pressure fuel is injected into the cylinder typically measured in psi or kPa or Mpa.	Increasing fuel injection pressure can increase power but may increase engine out NOx.
Fuel injection pulse width	Length of a fuel injection event (i.e., amount of time the fuel injector is open). Measured in units of time (usually milliseconds).	When injection pressure is increased, pulse width will decrease. On some engines, pulse width can be directly controlled by calibration.



Catalytic Air Pollution Control Commercial Technology 3rd edition. Ronald M. Heck (2009).



Source: <https://www.dieselnet.com/tech/>



Effect of Two-Stage Fuel Injection Parameters on NO_x Reduction Characteristics in a DI Diesel Engine. Energies ISSN 1996-1073. www.mdpi.com/journal/energies

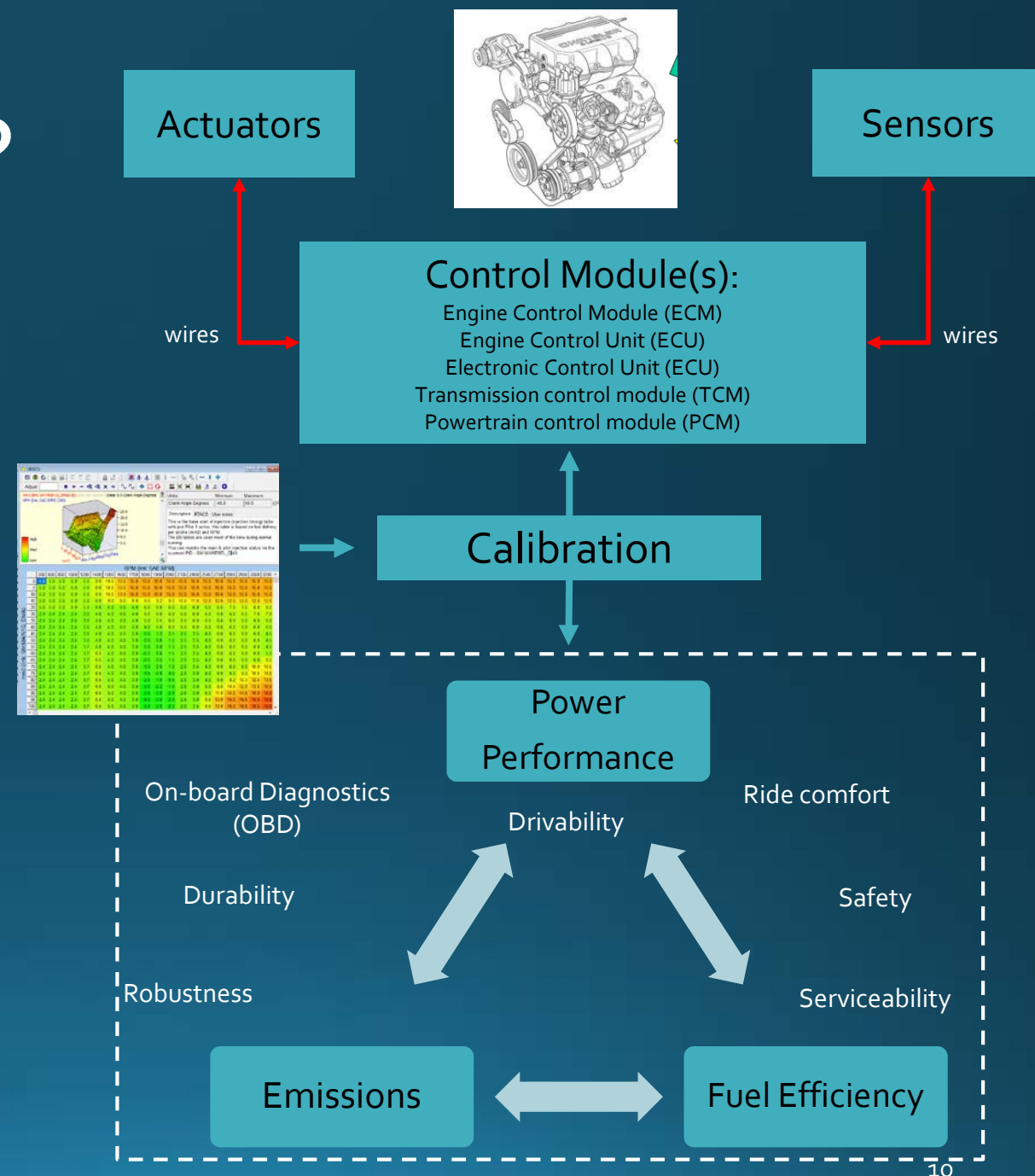
Information from sources provided under graphs to the right.

Common Emission Control Devices

- Common Diesel Aftertreatment Emission Controls
 - EGR (Exhaust Gas Recirculation)
 - Catalyst (Oxidative Catalyst, OC)
 - DPF (Diesel Particulate Filter)
 - SCR (Selective Catalytic Reduction)
- Common Gasoline Aftertreatment Emission Controls
 - EGR
 - Three way catalyst (TWC)
- Other Emission Control Devices
 - Calibration and On-board diagnostics (OBD)
 - Sensors (temperature, pressure, NO_x, PM, oxygen)
 - Direct injection, variable valve timing (gasoline)

What is Calibration?

- Generally, calibration is the electronic file that controls operation of engine or engine subsystems. It may also be referred to as tune or strategy.
 - fuel injection timing/pressure/quantity, AFR, boost pressure, torque limits, EGR flow rates, auxiliary emission control devices, etc.
- OEMs have a broad range of constraints, challenges, customer needs, and often competing, attributes/ requirements.
- Tuning – Process of modifying or adjusting calibration



What Requires Calibration?

It's Not Just the Engine

- Engine
- Transmission
- Exhaust & Emissions
- Brakes
- Traction Control/Stability Control
- HVAC
- Suspension



Source: Vehicle/Powertrain Calibration Engineering: What Is It and Why Is It For You? SAE International. William M. Sheeran, Julian Blair, Talus Park . September 26, 2013.

On-Board Diagnostics



ISO MIL Symbol



Data link connector (DLC)



Scan Tool

- OBD Functions
 - **Monitors the emissions-related components** for malfunction or deterioration that could cause a vehicle to fail to comply with the CAA emission standards. Examples:
 - EGR low flow, catalyst deficiency, missing substrates, unplugged sensors
 - **Records DTCs** – Must record diagnostic trouble codes (DTCs) when malfunctions are detected and under certain circumstances illuminate the malfunction indicator light (MIL) or even derate the engine (limit power, vehicle speed)
 - **Reports DTCs** – Must allow DTCs to be read by a scan tool through the data link connector (DLC)
- Vehicles <14,000 lbs GVWR (§86.007-17)
 - Generally referred to as "OBDII"
 - OBDII Phased in from 2005-2008
- Vehicles >14,000 lbs GVWR (§86.010-18)
 - Generally referred to as "HD OBD"
 - Phased in from 2010-2012

On-Board Diagnostics

- Required by Statute

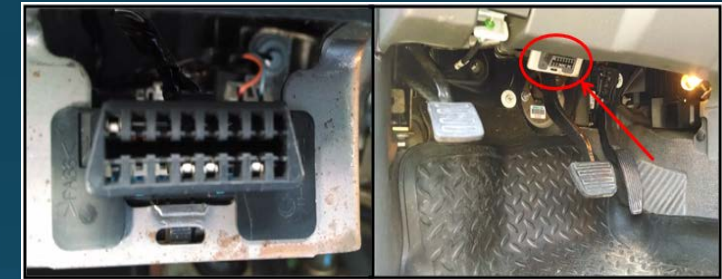
- CAA §202(m)(1) – “[T]he Administrator shall promulgate regulations . . . requiring manufacturers to install . . . diagnostics systems capable of . . . accurately identifying . . . emission-related systems deterioration or malfunction”

- CAA Criminal Prohibition

- CAA §113(c)(2)(C) – “Any person who knowingly . . . falsifies, tampers with, renders inaccurate, or fails to install any monitoring device or method required to be maintained . . . under [the CAA] shall, upon conviction, be punished by a fine pursuant to Title 18, or by imprisonment for not more than 2 years, or both.”



ISO MIL Symbol



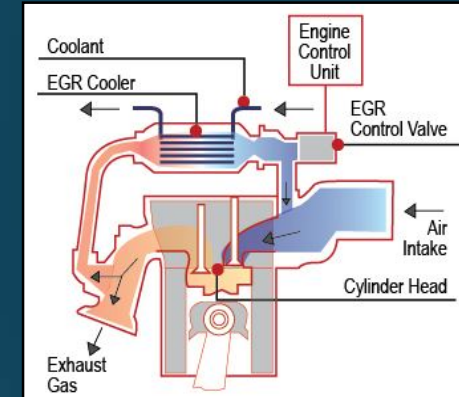
Data link connector (DLC)



Scan Tool

Exhaust Gas Recirculation (EGR)

- Engine out emission control found on 2003 and newer diesels
- Recirculates exhaust gases back into the combustion chamber
- Cooled and inert exhaust gases absorb heat released during combustion thus reducing the maximum temperature reached in the cylinder - NO_x formation increases as temperature increases
- Amount of EGR is controlled by a valve
 - Variable valve control (0-100%), set by calibration maps
 - Valve shut (0%) – no EGR

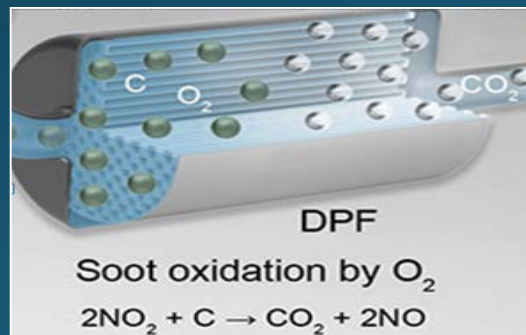
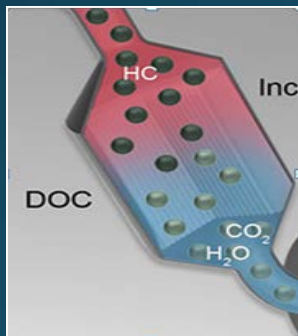


Source: TC, 2010



Exhaust Aftertreatment Emission Control Devices

- Oxidation Catalyst
 - Commonly a diesel oxidation catalyst (DOC) that controls unburnt hydrocarbons (HC)
 - Generally in 2003 and newer diesels
- DPF
 - Controls particulate matter (PM)
 - Generally found in 2007 and newer diesels
- SCR
 - Primarily controls NO_x using the injection of diesel exhaust fluid (DEF) prior to catalytic reduction
 - Generally found in 2010 and newer diesels



Exhaust Aftertreatment Emission Control Devices



DOC (2003 MY)



DOC + DPF (2007-2009 MYs)

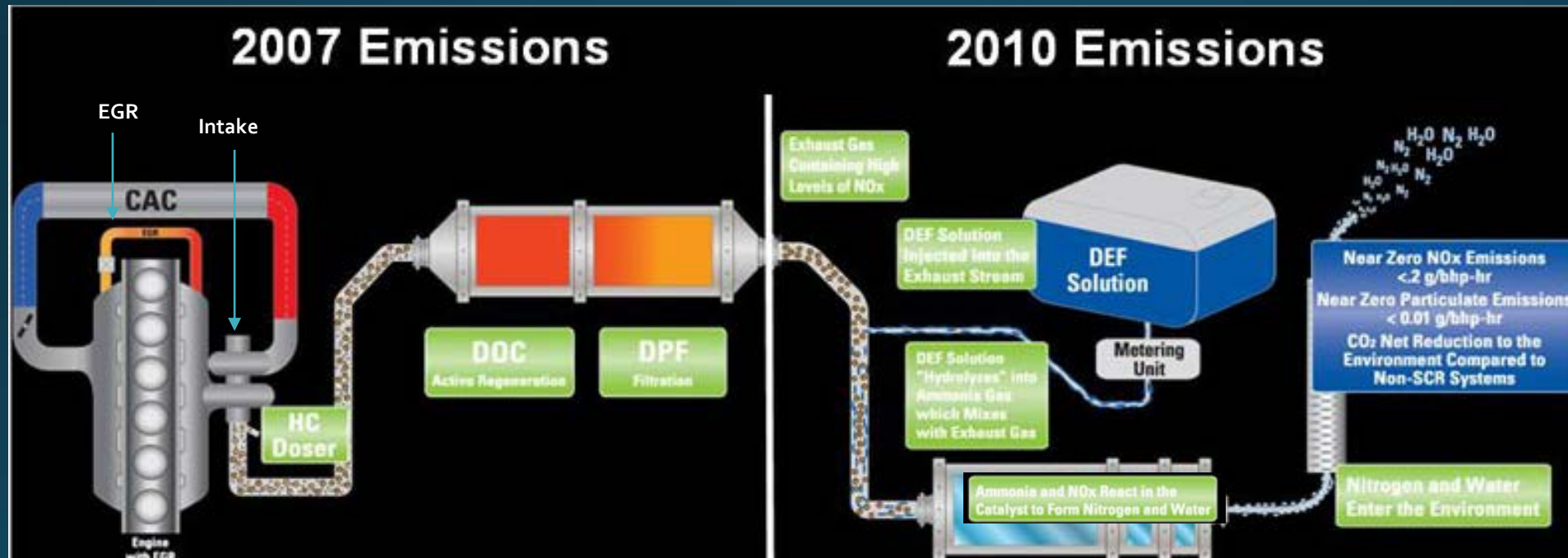


DEF tank for SCR
(2010+MY)



DPF + SCR + DOC (2010+ MYs))

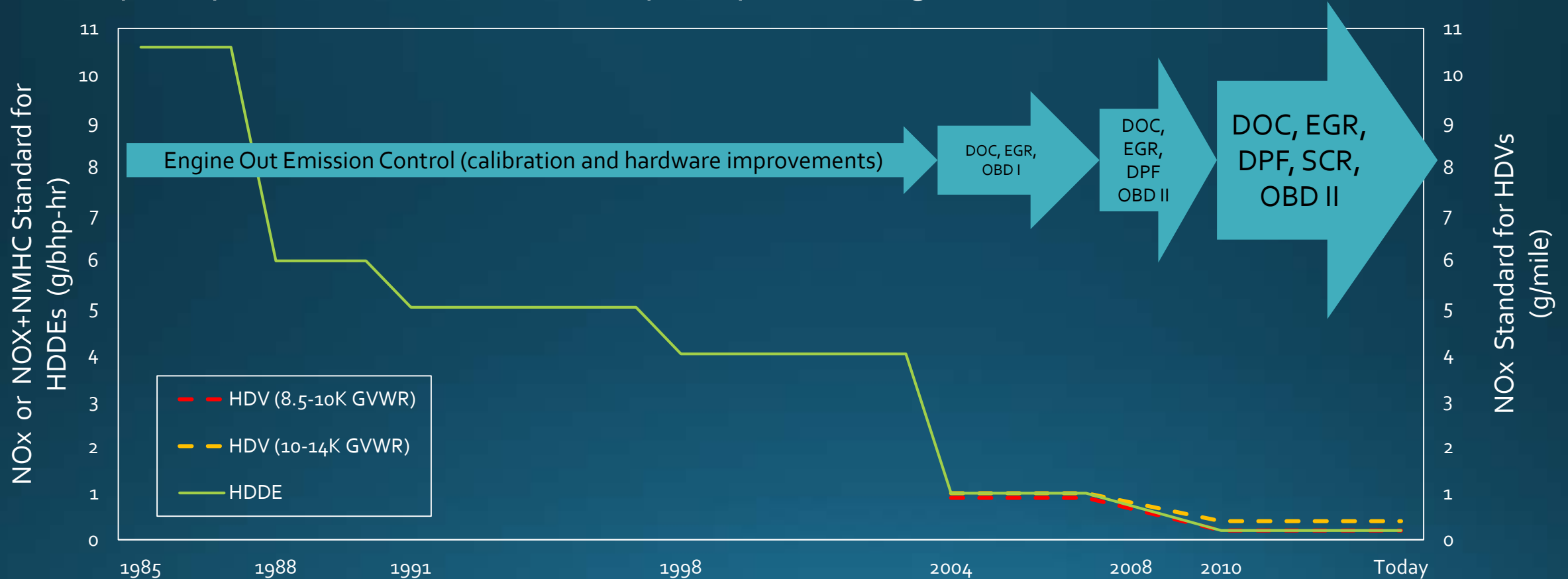
Common Configuration for Light-Duty Diesels



Source: <http://www.factsaboutscr.com/scr/scr-technology.aspx>

NOx Standards and Emission Control Devices Used by OEMs

Heavy-Duty Vehicles (HDVs) and Heavy-Duty Diesel Engines (HDDEs)



Source: <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA01.pdf>

Why buy an aftermarket defeat device?

“The Livewire TS unlocks your vehicle’s hidden performance by recalibrating your vehicle’s computer for Maximum Horsepower & Torque, Increase Throttle Response, Firmer Shifts and even Increased Fuel Mileage.”

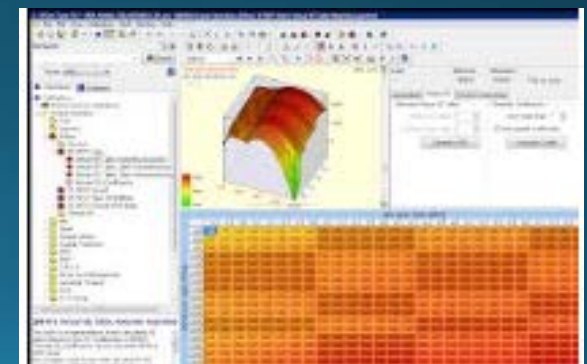
– *Punch-It Performance Advertisement*

Defeating EGR, DOC, DPF, and SCR may improve fuel economy (3 to 10 % increase based on EPA testing) but at the expense of up to 100’s or even 1,000’s of times higher emissions.



What is an Aftermarket Defeat Device?

- Aftermarket Defeat Device – “any part or component...where a principal effect...is to bypass, defeat, or render inoperative any device or element of design installed on or in a motor vehicle or motor vehicle...”
- Types of Defeat Devices
 - EGR Hardware Deletes
 - Exhaust Aftertreatment Delete Hardware (straight pipes)
 - Tuning – Calibration and OBD modifications



EGR Delete Hardware

- Includes:
 - EGR block off plates
 - EGR cooler deletes
- Calibration modification typically required
 - Disable OBD diagnostics
 - Disable EGR operation
- EGR delete hardware is not necessarily required with certain tuners



EGR electronic disablement (all EGR parts present and sensors plugged in)

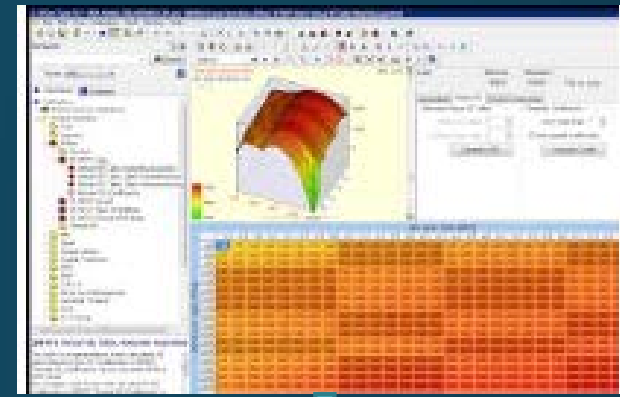
Exhaust Aftertreatment Delete Hardware

- Straight pipes
- Advertisement key words:
 - “Turbo back” or “Downpipe back”
 - Different from “cat back” systems
 - Model year 2003/2006 and newer diesels
- Calibration modification typically required
 - Disable OBD diagnostics
 - Disable operation
- Sensors (temperature, pressure, NOx, oxygen)
 - Contained in stock exhaust system and provide feedback to ECM
 - What to do with sensors depends on tuner (unplug/remove or leave plugged in)
 - Bungs vs. no bung straight pipes



Aftermarket Tuning

- Tuning = Modifying calibration file(s)
- Typically installed using a “tuner” through the vehicle’s data link connector (DLC)
- Tuning is required to make engine operate with EGR and exhaust aftertreatment deletes AND to prevent OBD from activating the check engine light and/or limp mode



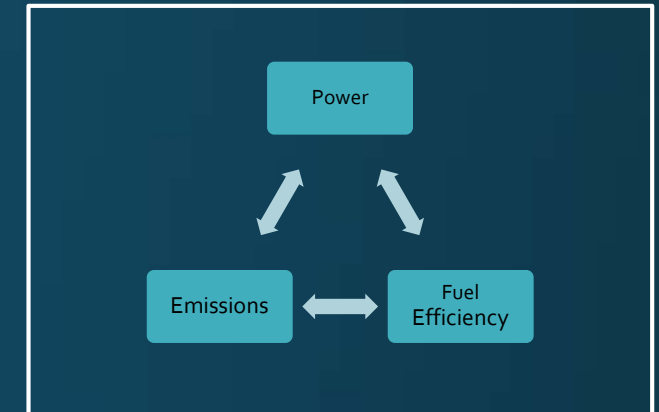
2009 Chevrolet Silverado Truck Automatic LMM 6.6 Litre (12628594).tun



Types of Tuning

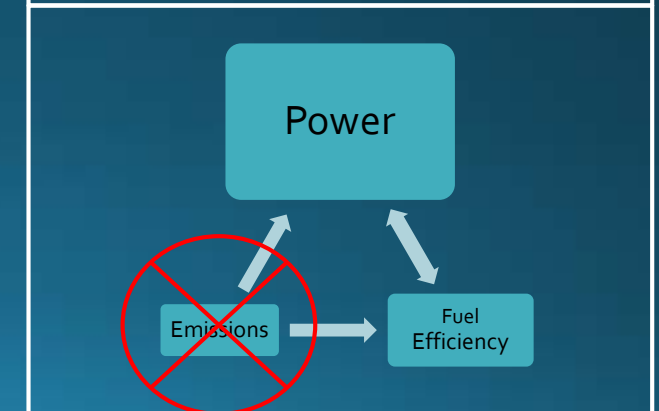
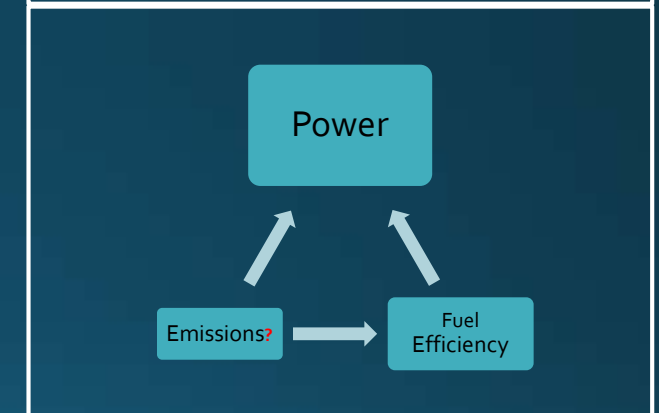
OEM Tuning

- Stock Calibration from OEMs - balance between power, fuel economy, drivability, and emissions standards, among other things

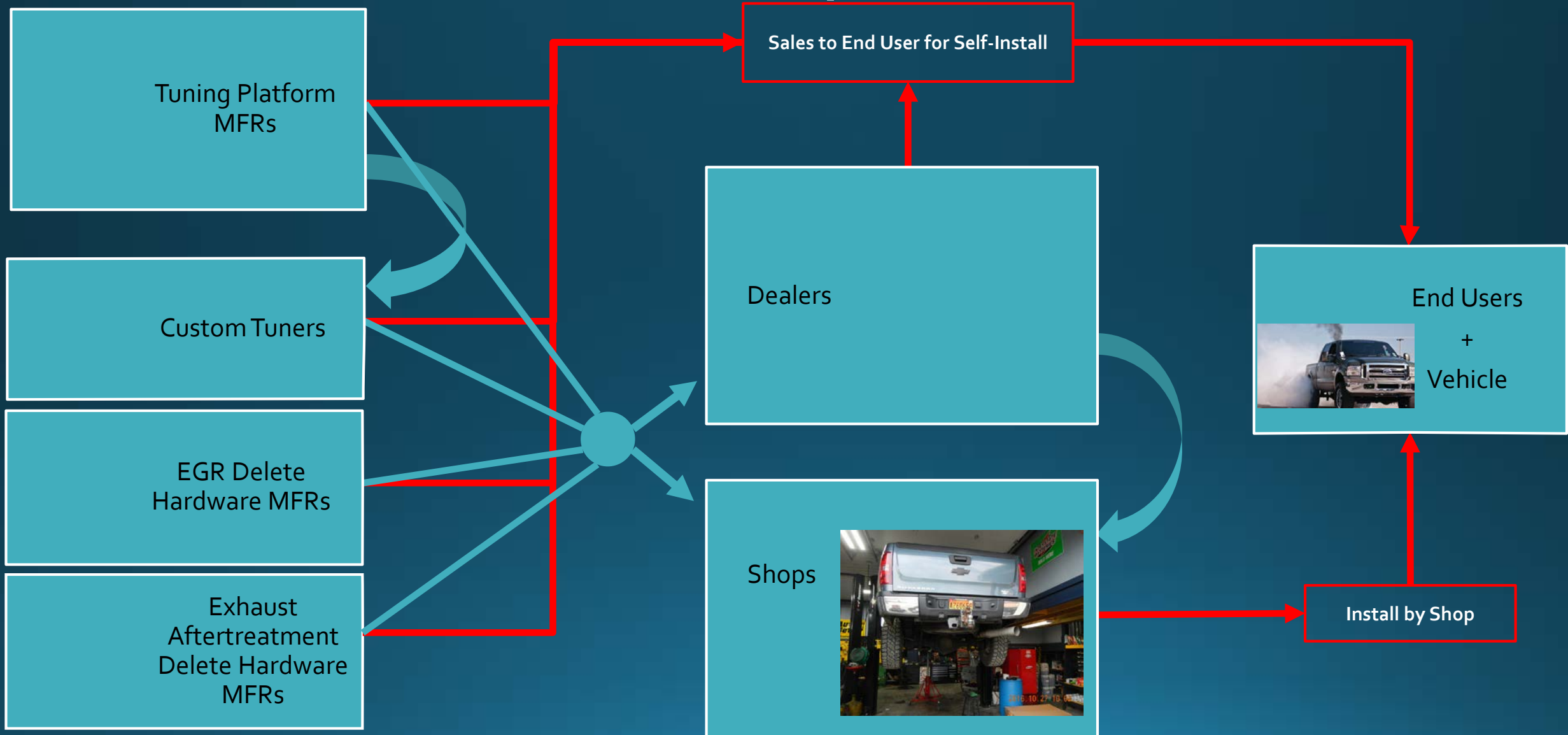


Aftermarket Tuning

- Emissions-Equipment Present Calibrations (aka "street" tunes): do not disable emission hardware but may still impact emissions by altering engine parameters that affect emissions (e.g., fueling quantity/timing/pulse, boost, diagnostics, torque limits).
- Emissions-Equipment Removed Calibrations (aka "race" tunes): disable emission controls (e.g., electronically disable EGR operation, allow straight pipe installation)



Aftermarket Industry Overview



EPA's Resolved Cases

Company Name	Type of Company	Type of Violations	Number of Violations
Caspers	Manufacturer	Tuners	44,000
Edge	Manufacturer	Tuners	9,000
H&S Performance	Manufacturer	Tuners	114,000
Spartan	Manufacturer	Tuners	4,211
Harley Davidson	Manufacturer	Tuners	340,000
Caspers	Manufacturer	Oxygen sensor simulators	44,000
Freerksen Trucking	Installer	Removed emission control devices	20
Antrim Diesel Services, Inc.	Installer	Removed emission control devices	5
Eisenhart Diesel, LLC	Installer	Removed emission control devices	3
Liberator Performance, Inc.	Installer	Removed emission control devices	3
Patterson's Diesel, Inc.	Installer	Removed emission control devices	2
Precision Automotive and Diesel, Inc.	Installer	Removed emission control devices	1
Trick Trucks Seven	Dealer	Sold defeat devices	32
Trick Trucks Eleven	Dealer	Sold defeat devices	9
Trick Trucks Ten	Dealer	Sold defeat devices	3
Boost Diesel Repair	Installer	Removed emissions control devices	30
Ryan's Diesel Service	Installer	Removed emissions control devices	23

Competition Motorsports

- Under the CAA there is no “competition only” exemption for motor vehicles or motor vehicle engines. If it’s an EPA-certified motor vehicle, the CAA prohibits parts or service that increase emissions.
- For decades, people have converted street vehicles to race vehicles, and as a matter of discretion, the EPA has not taken enforcement.
- The EPA’s focus is not on vehicles built or used exclusively for racing, but on companies that don’t play by the rules and that make and sell products that disable pollution controls on motor vehicles used on public roads. Many claim the products are “for competition use only,” but our investigations show that is often not the case.

Aftermarket Emissions Testing

Evaluate product before testing:

- Review of advertisements, user manuals
- CAA §208 Information Requests
- Purchase products as evidence
- Field inspections

During testing

1. Emissions-equipment present testing
 - Evaluate what calibration changes (e.g., advance timing, injection timing and pressure)
 - Quantify emissions to evaluate whether emissions are adversely affected
2. Emissions-equipment removed testing
 - Document tuner ability to disable emission controls (CAA §203(a)(3))*
 - Quantify impact on emissions



OBD should not allow engine operation with ECDs removed

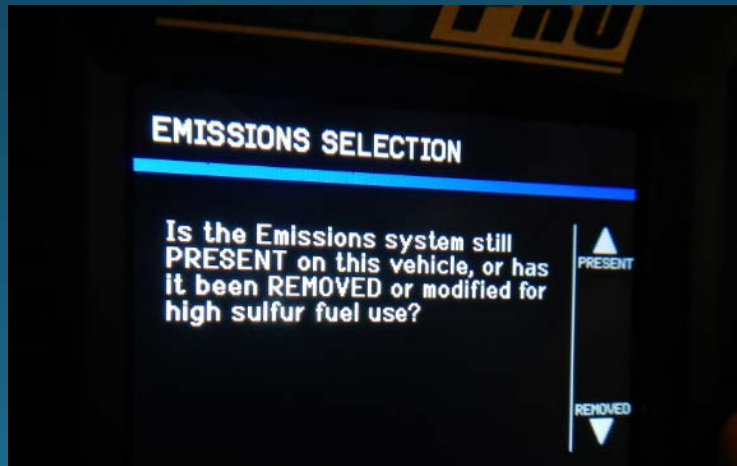
What is the emissions impact?

- As the following slides show, the emissions impact of tampering varies depending on the vehicle, the tuner (software changes), and the extent of the work done on the vehicle (hardware changes).
- The test results on the following slides were all conducted on the LA4 test cycle, which does not include a cold start. Emissions are typically highest during a cold start. Thus, these test results may not show the highest emissions that can result from these software and hardware changes.



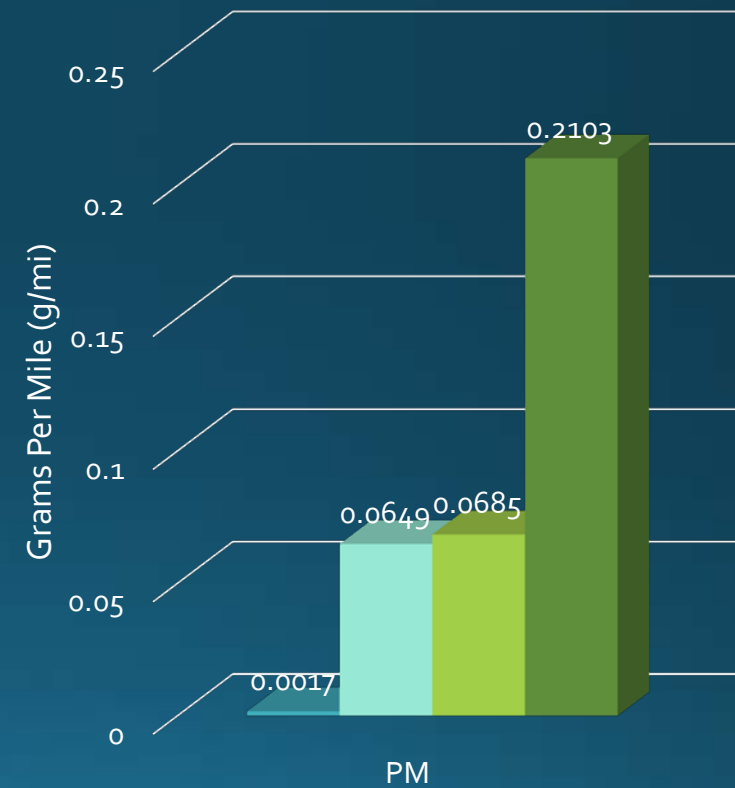
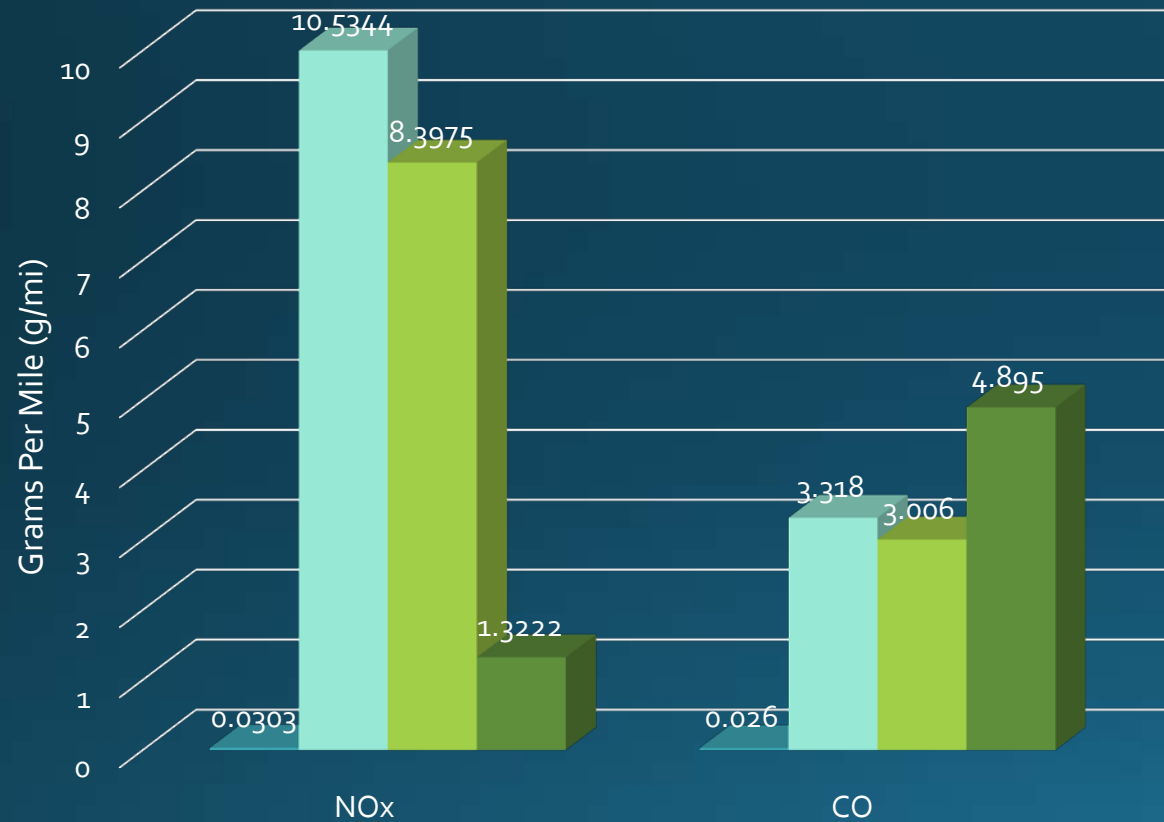
Testing Three Aftermarket Tuners

- Test Vehicle
 - 2011 Ford F-350 (EF: BFMXDo6.771C)
 - 6.7 Liter Powerstroke Diesel Engine
 - Odometer: 33,933 miles
 - Certified with EGR, DOC, DPF, SCR, and OBD II
- Test results on following sides are for the LA4
 - First 2 phases only of the FTP
 - Hot starts only – city driving
- Objective: Demonstrate ability to electronically disable EGR, DPF, DOC, SCR in calibration and compare emission results against stock baseline results.
- Logged and analyzed live engine data



EPA Tuner Emissions Tests

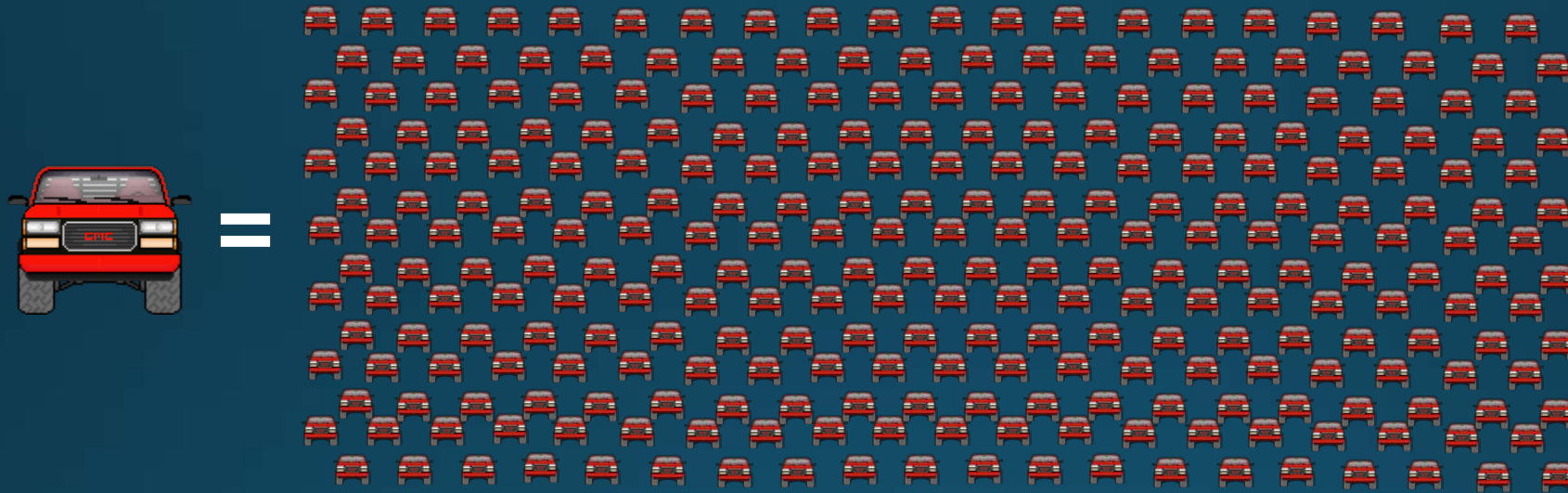
Stock Calibration/Equipment Versus Emissions-Equip. Removed Tuners
2011 Ford F-250 6.7Powerstroke



Second and Third test: EGR electronically disabled by tuner. DOC, DPF, and SCR replaced with straight pipe and disabled by tuner in calibration.

Fourth Test: EGR not disabled electronically by tuner. DOC, DPF, and SCR replaced with straight pipe and disabled by tuner in calibration.

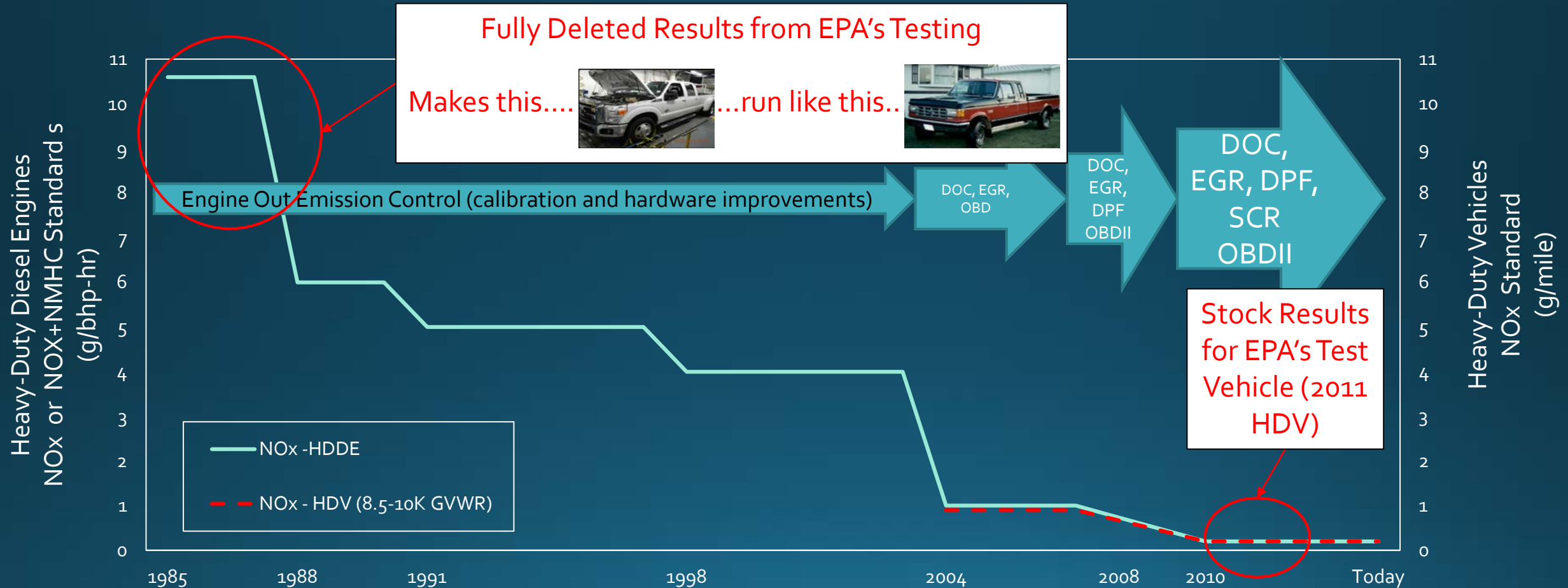
Emissions Increase Due to Full Delete



These test results show the increase in NO_x, NMHC, CO, and PM when a tuner enables a full delete of the vehicle. These tests were conducted without the SCR, DPF, DOC, and EGR emission controls.

- Tailpipe NO_x increased ~310x
- Tailpipe NMHC increased ~1,140x
- Tailpipe CO increased ~120x
- Tailpipe PM increased ~40x

Emissions Increases From Emissions Delete



Source: <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OAo1.pdf>